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Testing the Efficiency of the Wine Market using Unit Root Tests with Sharp and Smooth Breaks

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Abstract

This paper examines the efficient market hypothesis for the wine market using a novel unit root test while accounting for sharp shifts and smooth breaks in the data. We use monthly data for five wine price indices to draw the following conclusions: (a) We find evidence of structural shifts and nonlinearity in the wine indices; (b) We cannot reject non-stationarity in the five wine series based on the conventional linear unit root tests; (c) However, when we use the same tests but account for sharp shifts and smooth breaks, we are able to reject the unit root null for each of the wine indices. Overall, our results suggest that the wine market is inefficient when we incorporate breaks. We provide some practical and policy implications of our findings.

JEL Codes: C22, G1.
Keywords: Wine market, efficiency, sharp and smooth breaks, unit root tests.

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1. Introduction

The concept of market efficiency has been drawing considerable attention from policy makers, investors, and scholars. The efficient market theory follows from the efficient market hypothesis, which states that current asset prices fully reflect all available information about the intrinsic value of the asset (Fama, 1970). Practically, this means that asset returns are not predictable and thereby investors cannot systematically earn excess return from their investment strategies. In contrast, asset returns in inefficient markets can be predicted on the basis of past price changes, suggesting the possibility of investors to outperform the market. For regulators and policy-makers, enhancing the flow of market information to have speedier price discovery, through the improvement in legal and regulatory frameworks and in transparency, is an endless burden. For scholars, the search for inefficient markets and ways to exploit them remains a rich and appealing research ground.

While the theory of price efficiency has been studied extensively in stock markets (Fama, 1970; Urquhart and McGroarty, 2016), bond markets (Hotchkiss and Ronen, 2002), credit default swaps (CDS) markets (Kiesel et al., 2016), exchanges rates (Charles et al., 2012) and commodities (Smith, 2002 for gold; Charles and Darne, 2009 for crude oil, and Kristoufek and Vosvrda for 25 commodities futures), it remains unexplored in the fine wine market. The latter has recently captured wide attention from the media and financial press given that fine wines represent an alternative and valuable investment asset (Strochmann, 2012; Masset and Handerson, 2010; Bouri, 2015). According to Barclays (2012) about one quarter of high-net-worth people own a wine collection that is worth an average of 2% of their wealth.

Like markets for other conventional financial assets such stocks, bonds and commodities, investing in fine wines is becoming easier with the introduction in 2000 of the London International Vintners Exchange (Liv-ex). This auction market has brought transparency and liquidity to the market place. Liv-ex publishes leading fine wine benchmarks that are used by several wine investment funds (see, among others, The Wine Investment Fund in Bermuda, Lunzer Wine Fund in British Virgin Islands, Patrimoine Grands Crus in France). The introduction of such wine funds has also accelerated the pace of financialization and made fine wine investment more accessible.

In addition to its consumption role, fine wine is appreciated by wine private collectors because it is a store of value. Compared to conventional financial assets, wine prices are affected by non-financial factors that include the name of the producer, ranking of the wine, weather, year of vintage, grape composition, reputation, and production technology (Hadj et al., 2008; Storchmann, 2012). Climate change has also been related to fine wine prices and quality (Ashenfelter and Storchmann, 2014). Accordingly, wine economists suggest that wine return is weakly correlated with the fluctuations in equity and bond markets. In this regard, a first strand of research has considered the diversification capabilities of fine wines within bond and equity portfolios during tranquil and turbulent periods. Fogarty (2007, 2010) highlights the importance of adding fine wine investment to enhance the risk-adjusted return of a portfolio of stocks and bonds. Sanning et al. (2008) stress on the ability of fine wine investment to diversify equity portfolios. Masset and Henderson (2010) show that fine wines are essential to investors who are concerned about the skewness of their equity portfolios. In addition to the positive impact on return and risk, Masset and Weisskop (2010) show the effects of wine investment on portfolio skewness and kurtosis. They also reveal the defensive characteristics of fine wine during times of market stress. In examining the relationship across the performance of stock markets, interest rates, and agriculture and food industries, Kourtis et al. (2012) point to the advantages of diversification across the different wine markets in Europe. Bouri (2014) argues that fine wines can act as a safe have against adverse movements in equities given the negative relationship between fine wine return and its conditional volatility. In addition the hedging capability, Bouri (2015) also shows that fine wines have a safe haven property against world major equities during times of stress.

Another strand of research has examined fine wines in relation to macro-economic variables. Anderson and Wittwer (2013) show the importance of accounting for bilateral real exchange rates and the growth in China's import demand in modeling the global wine market. Trellis Wine Investments (2013) indicate that fine wine is a good hedge against inflation risk and also insensitive to the US stock market uncertainty. Cevik and Sedik (2014) show the importance of macroeconomic variables in determining fine wine price, in particular the demand growth from emerging economies and the abundant global liquidity. Jiao (2016) shows that both the weakening in the US dollar and the demand from emerging markets have the most significant impact on fine wine prices. Qiao and Kuok Kun Chu reveal the predictability of GDP in developed economies based on fine wine prices. Faye et al. (2015) show a strong effect of the global equity market on wine prices over the period 2003-2012.

The above literature clearly indicates a lack of studies on the efficiency in the wine market. If fine wines represent an asset class on its own, as suggested by prior studies, its related literature must be extended to cover wine market efficiency which matters to all market participants. In fact, the value added by portfolio managers and investment strategists depends on whether the market is efficient or not. Furthermore, it is not clear whether the above developments in the wine market has contributed to making fine wine returns unpredictable or following a random walk.

In this paper, we therefore aim to contribute to the extant literature of market efficiency, and in particular, for the wine market by examining its efficiency using a unit root test that allows us to account for potential sharp shifts and smooth breaks in wine prices. It is well-known that the persistence parameter of a process may be overestimated if structural breaks are omitted or ignored from the unit root tests, consequently decreasing the power to reject a unit root when the stationarity alternative is true (Perron, 1989). Hence, we model breaks in our unit root testing methodology, with the regime changes being both smooth and sharp, given that we use monthly data, and hence, both types of structural breaks are likely to co-exist. Our methodology also allows us to model any number of sharp breaks, unlike standard unit root tests which only permit either one (Zivot and Andrews, 1992) or two breaks (Lumsdaine and Papell, 1997; Lee and Strazicich, 2003). Hence, our approach is more general, and robust to misspecifications due to less number of breaks being specified, and also because of omission of smooth breaks. To the best of our knowledge, this is the first paper to test for efficiency in the five widely used indices of wine prices, by accounting for smooth and sharp breaks.

The remainder of the paper is organized as follows: Section 2 discusses the methodology. In section 3 we present the data and the results, and section 4 concludes.

2. Methodology

We use a unit root test by taking into account both sharp shifts and smooth breaks. Let y_t denote the log of wine price in our case and ε_t a serially uncorrelated error term. An AR(q) process for log wine price with drift *a* and deterministic trend t is given by:

$$y_t = a + bt + \sum_{i=1}^{q} \gamma_i y_{t-1} + \varepsilon_t, \quad t = q+1, q+2, ..., n. \tag{1}$$

The sum of the autoregressive coefficients is $\alpha = \sum_{i=1}^{q} \gamma_i$ - a measure of persistence that we will focus on in our study. We can rewrite Equation (1) as follows:

$$y_t = \alpha y_{t-1} + a + bt + \sum_{i=1}^{q-1} \phi_i \Delta y_{t-i} + \varepsilon_t \tag{2}$$

Here we can run the usual unit root test. If $\alpha = 1$ then wine price has a unit root and, therefore, shocks have permanent effects on wine price. If we have $\alpha < 1$, then wine price is stationary. In this case shocks have only temporary effects on wine price.

Following Bahmani-Oskoee *et al.,* (2014, 2015), we can model mean reversion properties in wine price with both sharp shifts and smooth breaks in the estimation of a level and trend equation as follows:

$$y_t = \alpha + \beta t + \sum_{l=1}^{m+1} \theta_l DU_{l,t} + \sum_{l=1}^{m+1} \rho_l DT_{l,t} + \sum_{k=1}^{n} \gamma_{1,k} \sin(\frac{2\pi kt}{T}) + \sum_{k=1}^{n} \gamma_{2,k} \cos(\frac{2\pi kt}{T}) + \varepsilon_t \tag{3}$$

In equation (3), *t*, *T*, and *m* are time trend, sample size and the optimum number of breaks, respectively. The other regressors are defined as the following:

$$DU_{k,t} = \begin{cases} 1 & if \quad TB_{k-1} < t < TB_k \\ 0 & otherwise \end{cases} \tag{4}$$

$$DT_{k,t} = \begin{cases} t - TB_{k-1} & if \quad TB_{k-1} < t < TB_k \\ 0 & otherwise \end{cases} \tag{5}$$

Terms *DU* and *D*T are entered in the model to capture the sharp shifts.[1] Following the work of Gallant (1981), in order to obtain a global approximation from the smooth transition, we use the Fourier approximation and enter both terms of $\sum_{k=1}^{n}\gamma_{1k}\sin(\frac{2\pi kt}{T})$ and $\sum_{k=1}^{n}\gamma_{2k}\cos(\frac{2\pi kt}{T})$ into the model; where *n* and *k* present the number of frequencies that contained in the approximation and equal to $\mathrm{n} \leq \frac{\mathrm{T}}{2}$ and particular frequency, respectively.

Estimation of equation (3) involves with three issues, the choice of m, the choice of n, and the choice of *k*. As noted by Becker et al. (2004), it is reasonable that we restrict *n*=1, because if $\gamma_{1,k} = \gamma_{2,k} = 0$ can be rejected for one frequency, then the null hypothesis of time invariance is also rejected. Also Enders and Lee (2012) noted that imposing the restriction *n*=1 is useful in order to save the degrees of freedom and prevent from over-fitting problem. Hence we re-specify the equation (3) as follows:

$$y_t = \alpha + \beta t + \sum_{l=1}^{m+1}\theta_l DU_{l,t} + \sum_{i=1}^{m+1}\rho_i DT_{i,t} + \gamma_1 \sin(\frac{2\pi kt}{T}) + \gamma_2 \cos(\frac{2\pi kt}{T}) + \varepsilon_t \tag{6}$$

It is important to note that we can remove the impact of possible structural breaks on wine price based on the information of break dates. We follow the procedure adopted by Tsong and Lee (2011) to reconstruct time series of wine price taking into account both sharp shifts and smooth breaks as follows:

[1] Equation (3) is not only an extension of Enders and Holt (2012) but also a combination of Carrion-i-Silvestre *et al.* (2006) and Becker *et al.* (2006) tests.

$$y_t = wine_t - \hat{\alpha} - \hat{\beta}t - \sum_{l=1}^{m+1}\hat{\theta}_l DU_{l,t} - \sum_{i=1}^{m+1}\hat{\rho}_i DT_{i,t} - \hat{\gamma}_1 \sin(\frac{2\pi kt}{T}) - \hat{\gamma}_2 \cos(\frac{2\pi kt}{T}) + \varepsilon_t \quad (7)$$

where y_t is wine price adjusted by the effect of possible structural breaks (for both sharp shifts and smooth breaks), $wine_t$ is log price price, DU_t and DT_t are the same as those in Equation (6) . For details about how to estimate Equation (6), interested readers can refer to Bahmani-Oskoee *et al.,* (2014, 2015).

3. Data and Empirical Results

We use monthly data on five wine market price indices maintained by London International Vintners Exchange (Liv-ex). (Liv-ex) is an exchange for investment-grade wine based in London. Liv-ex, which was founded in 1999, provides a marketplace where wine merchants are able to trade wine, and also publishes five wine price indices based on these transactions which are widely used to gauge general price developments for the "fine wine" market in general. The five indices considered in this paper are:

(a) The Liv-ex Fine Wine 50 (Liv-ex 50) index, which tracks the price movement of the most heavily traded commodities in the fine wine market - the Bordeaux First Growths. It includes only the ten most recent vintages (excluding En Primeur, currently 2004-2013), with no other qualifying criteria applied. The data covers the monthly period of 1999:12-2016:04;

(b) The Liv-ex Fine Wine 100 (Liv-ex 100) index is the industry leading benchmark. It represents the price movement of 100 of the most sought-after fine wines on the secondary market. The data period covered in this cases is 2001:08-2016:05;

(c) The Liv-ex Bordeaux 500 is Liv-ex's most comprehensive index and reflects trends in the wider fine wine market. It represents the price movement of 500 leading wines and is calculated using the Liv-ex Mid Price. The index spans the period of 2004:01-2016:05;

(d) The Liv-ex Fine Wine 1000 (Liv-ex 1000) tracks 1,000 wines from across the world using the Liv-ex Mid Price, and covers the period of 2003:12-2016:04;

(e) Finally, the Liv-ex Fine Wine Investables (Liv-ex Investables) index tracks the most "investable" wines in the market around 200 wines from 24 top Bordeaux chateaux. In essence, it aims to mirror the performance of a typical wine investment portfolio. The index data starts in 1990:5 and ends in 2016:05; hence it goes further back than any other Liv-ex indices.

The data on these five indices have been sourced from Datastream maintained by Thomson Reuters. All indices are transformed to their natural logarithms, with the start and end dates being purely driven by data availability at the time of writing this paper.

We present the summary statistics of the log of the wine indices in Table 1. The mean and variance in the data across the five indices are quite similar. In addition, all the indices are skewed to the left and depict excess kurtosis. So, when we use a formal test of normality (Jarque-Bera statistic), we conclude that all the series are non-normally distributed, with the null of normality rejected at the highest level of significance.

[INSERT TABLE 1]

To test the efficiency of the wine market, we start with the conventional linear unit root and/or stationarity tests namely, the Augmented Dickey and Fuller (1979, ADF), Phillips and Perron (1988, PP), Elliot et al.'s (1996) GLS-detrended Dickey-Fuller (DF-GLS), Kwiatkowski et al. (1992, KPSS), and Ng and Perron (NP, 2001). The tests are first applied to the log-levels with a constant, and constant and trend in the unit root test equations. As can be seen from Table 2a, the null of unit root cannot be rejected even at ten percent level of significance for the ADF, PP, DF-GLS and NP tests. While, the null of stationarity for the KPSS test is rejected at the one percent level of significance. The fact that all the five indices are integrated or order one (I(1)) under a constant, and constant plus trend in testing equations, is vindicated by the fact that the first-differences of the series are found to be stationary, i.e., I(0), at the highest level of significance, as observed from Table 2b. In other words, using standard unit root tests, which does not account for breaks, we would conclude that the wine market is efficient.

[INSERT TABLE 2]

Next, all the above tests are now applied to adjusted series that account for sharp shifts and smooth breaks as shown in Equation (7). The results are presented in Table 3, with the testing equation of unit root including only a constant. Based on the ADF, PP, DF-GLS and NP tests, we reject the null hypothesis of unit root at one percent level of significance. Similarly, using the KPSS test, we cannot reject the null hypothesis of stationarity even at the ten percent level of significance. These findings suggest that all the five wine indices are stationary in log-levels, i.e., the wine market is not efficient.

[INSERT TABLE 3]

Recall that we have used the Fourier approximation to 'mimic' the time-varying parameter and hence nonlinearity in the wine indices. In Table 4, we present the optimum breaks and frequency from the mean reverting function in equation (6) alongside with the estimated *F*-statistic that enables us to test for the absence of the nonlinear component in equation (6). In other words the *F*-statistic is computed by comparing the sum of squared residual (*SSR*) from equation (6) with the nonlinear component (unrestricted model) with the *SSR* from equation (6) without the nonlinear component (restricted model). However, the critical values for the *F*-test is non-standard due to nuisance parameters (Becker et al. 2004), hence we follow Bahmani-Oskooee et al. (2014, 2015) and use Monte Carlo simulation to compute the critical values based on 10000 replications. We fixed k at a maximum of 7 and m at a maximum of 5. From Panel A of Table 4, we observe that the optimum frequency vary from one wine index to the other with a minimum of 4 and maximum of 6 optimal frequencies. The computed *F*-statistics are in all cases greater than the critical values, even at the one percent level. Hence, the mean reverting function with the nonlinear component is accepted in favour of the one without the nonlinear component. Turning to the results from panel B of Table 4, we observe that there are 6 breaks in each of the wine series, thus vindicating the decision to model sharp breaks besides the smooth ones. We note that, majority of the breaks are concentrated during and after the financial crisis period.

[INSERT TABLE 4]

Finally, we present the time paths of the wine indices in Figures 1a-e. The sub-figures shows that there are structural shifts in the wine series, and hence points to the need to allow for both sharp shifts and smooth breaks in testing for a unit root and/or stationarity. We superimpose the predicted time paths from our model on the actual time paths, and we observe that the predicted series tracks the dynamic behaviour of the actual wine series well, suggesting that the decision to include the dummy variables and Fourier approximations is quite reasonable since the data generating process are indeed nonlinear.

[INSERT FIGURE 1]

4. Conclusion

The question as to the efficiency of a particular market is usually of interest to both investors and practitioners. This study investigated the efficiency of the wine market using a novel unit root test that accounts for both sharp shifts and smooth breaks in the data, with the latter captured using Fourier approximation. Our analysis involves monthly data on five wine indices maintained by London International Vintners Exchange. We conducted a host of conventional unit root tests on the original series and our newly constructed series that account for both sharp shifts and smooth breaks. Results based on these tests are in contrast with each other, with the tests applied to the original series were not able to reject the null of unit root, while the tests on the transformed series rejected the null of unit root for all the wine indices. Formal statistical tests provided evidence of structural breaks and nonlinearity in the data, and, hence, vindicated the decision to model both sharp and smooth breaks. Our findings have some important implications. They point to the importance of allowing for sharp shifts and smooth breaks as in modelling the wine market, since failure to do so lead to the conclusion that the wine market prices are unit root processes. More importantly, the evidence of mean reverting behaviour in all the wine series suggests that shocks to the markets are short-lived and wine returns can be predicted; hence, the market is not efficient. In other words, since wine prices do not fully reflect all available information in the market, market participants can incorporate any hidden information into their investment and/or management strategies and consequently make excessive gains from participating in the market. While it is understandable that the role of policy is limited here, since shocks are temporary, and somehow there are forces that will bring the market to its equilibrium in the long run; policies that improve investors' access to market information may act as incentives to participate in such market, especially for smaller investors. Realizing that, asymmetric information is the basic source of inefficiency-mispricing, bubbles, crashes, transparency in trade can help to reduce the observed inefficiency in the wine market. Notably, the lack of a clear differentiation between the three levels of market efficiency, weak form, semi-strong and strong form efficiency, as documented by Fama (1970), is an important limitation to your research. This would be an interesting topic for future research.

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Table 1. Descriptive Statistics of the Log of Wine Indices

	Variable				
Statistic	Liv-ex 50	Liv-ex 100	Liv-ex Bordeaux 500	Liv-ex 1000	Liv-ex Investables
Mean	5.2151	5.2252	5.2547	5.2501	4.6310
Median	5.4157	5.4685	5.3812	5.3728	4.6019
Maximum	6.0990	5.8990	5.7033	5.6337	5.9130
Minimum	4.4645	4.5249	4.5882	4.5978	2.9118
Std. Dev.	0.5303	0.4561	0.3474	0.3387	0.8874
Skewness	-0.0999	-0.4540	-0.8355	-0.8466	-0.5054
Kurtosis	1.3823	1.5811	2.2335	2.2062	2.1930
Jarque-Bera	21.8089	21.0464	20.9843	21.7112	21.8201
Probability	0.0000	0.0000	0.0000	0.0000	0.0000
Observations	197	178	149	149	313

Note: Std. Dev. stands for standard deviation, while probability corresponds to the Jarque-Bera test of normality.

Table 2a. Unit Root Tests in Log-Level

	ADF		PP		DF-GLS		KPSS		NP	
Variable	Constant	Constant + Trend	Constant	Constant + Trend	Constant	Constant + Trend	Constant	Constant + Trend	Constant	Constant + Trend
Liv-ex 50	-1.275	-1.246	-1.144	-1.161	0.191	-1.398	1.485*	0.222*	0.229	-4.442
Liv-ex 100	-1.326	-1.072	-1.353	-0.895	0.122	-1.197	1.367*	0.313*	0.128	-3.542
Liv-ex Bordeaux 500	-1.982	-1.122	-1.807	-0.882	0.424	-0.982	1.173*	0.316*	0.422	-2.406
Liv-Ex 1000	-2.058	-0.798	-1.994	-0.654	0.414	-1.120	1.233*	0.327*	0.412	-3.223
Liv-Ex Investables	-1.841	-1.379	-1.777	-1.259	1.298	-1.225	1.863*	0.227*	0.836	-4.122

Notes: KPSS test has a null of stationarity, while the other tests have a null of unit root; C (C+T) indicates that the unit root testing equation has a constant (constant and trend); * indicates rejection of the null hypothesis at 1percent level.

Table 2b. Unit Root Tests in First-Difference

	ADF		PP		DF-GLS		KPSS		NP	
Variable	Constant	Constant + Trend	Constant	Constant + Trend	Constant	Constant + Trend	Constant	Constant + Trend	Constant	Constant + Trend
Liv-ex 50	-7.245*	-7.277*	-7.302*	-7.293*	-5.505*	-6.463*	0.174	0.125	-45.750*	-56.819*
Liv-ex 100	-6.891*	-6.943*	-6.885*	-6.937*	-6.729*	-6.976*	0.247	0.117	-57.480*	-59.956*
Liv-ex Bordeaux 500	-6.237*	-6.480*	-6.124*	-6.548*	-4.927*	-5.537*	0.333	0.077	-36.096*	-42.097*
Liv-Ex 1000	-4.464*	-6.578*	-6.015*	-6.488*	-4.221*	-4.375*	0.429	0.085	-29.338*	-30.894*
Liv-Ex Investables	-6.992*	-13.616*	-14.728*	-14.652*	-3.456*	-5.673*	0.268	0.071	-20.633*	-48.101*

Note: See Notes to Table 2a.

Table 3. Unit Root Tests in Log-Levels Accounting for Smooth and Sharp Breaks

Variable	ADF	PP	DF-GLS	KPSS	NP
Liv-ex 50	-8.671*	-5.157*	-3.730*	0.020	-24.526*
Liv-ex 100	-7.997*	-4.701*	-3.983*	0.019	-29.098*
Liv-ex Bordeaux 500	-7.036*	-6.697*	-4.100*	0.028	-27.265*
Liv-Ex 1000	-6.826*	-5.419*	-6.808*	0.024	-55.967*
Liv-Ex Investables	-7.759*	-7.925*	-7.650*	0.016	-83.221*

Note: See Notes to Table 2a.

Table 4: Estimation results for the Mean Reverting function (Equation (6))

Panel A: The results for optimum frequency and the *F*-statistic and its critical values

Index	Optimum Frequency	*F*-stat	90%	95%	97.50%	99%
Liv-ex 50	5	68.549	2.362	3.068	3.729	4.832
Liv-ex 100	6	69.395	2.421	3.097	3.828	4.875
Liv-ex Boradeaux500	4	77.32	2.354	3.076	3.771	4.744
Liv-ex 1000	5	45.81	2.324	3.139	3.802	4.657
Liv-ex Investables	5	90.47	2.343	3.016	3.606	4.486

Panel B: The results for sharp drift (break) dates in Equation (6)

Liv-ex 50	2001:2	2004:6	2006:4	2009:7	2012:1	2014:1
Liv-ex 100	2003:1	2005:9	2006:8	2007:6	2009:8	2012:1
Liv-ex Broadeaux500	2005:6	2007:04	2008:9	2011:9	2013:3	2014:7
Liv-ex 1000	2004:1	2005:7	2007:1	2008:3	2010:5	2012:2
Liv-ex Investables	1992:2	1997:7	2004:9	2007:1	2011:3	2014:1

Figure 1. Plots of Actual and Predicted Log of Wine Indices:

Figure 1a. Liv-ex 50 Fine Wine Index

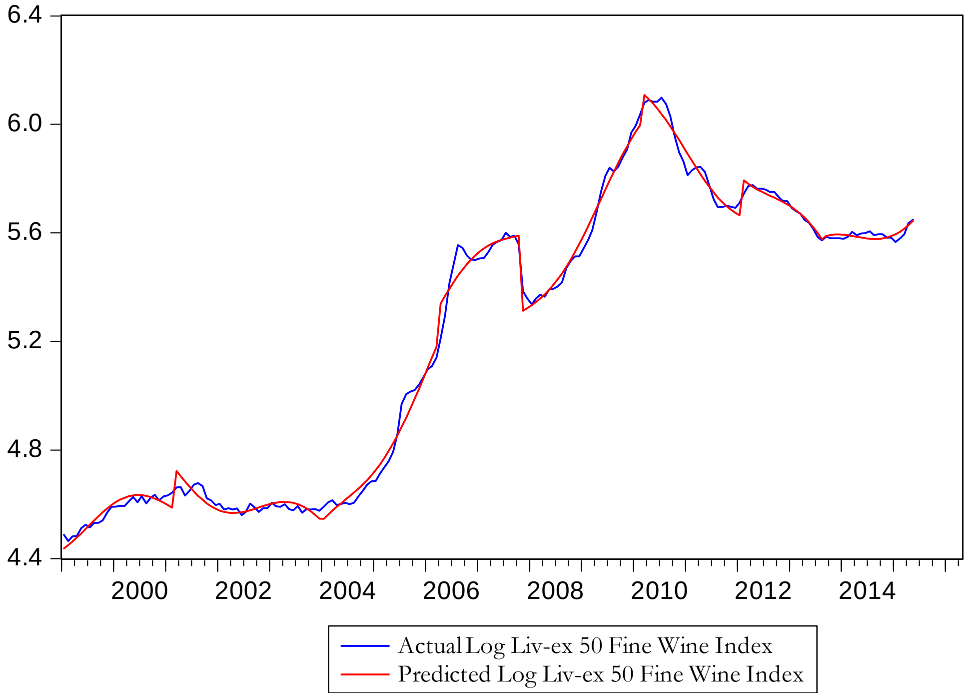

Figure 1b. Liv-ex 100 Fine Wine Index

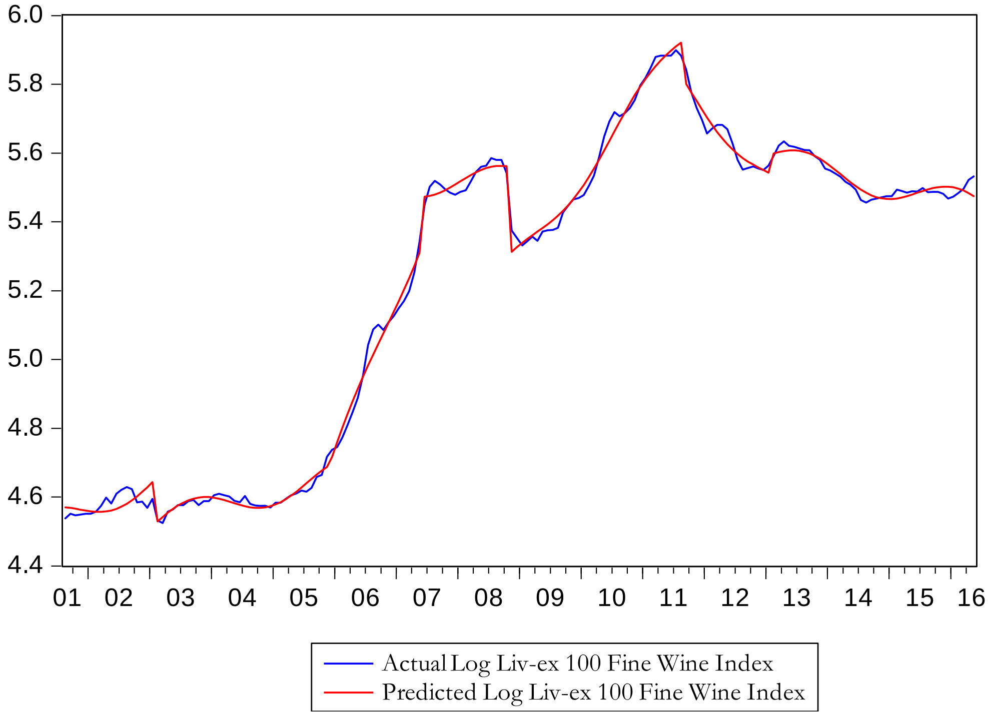

Figure 1c. Liv-ex Bordeaux 500 Fine Wine Index

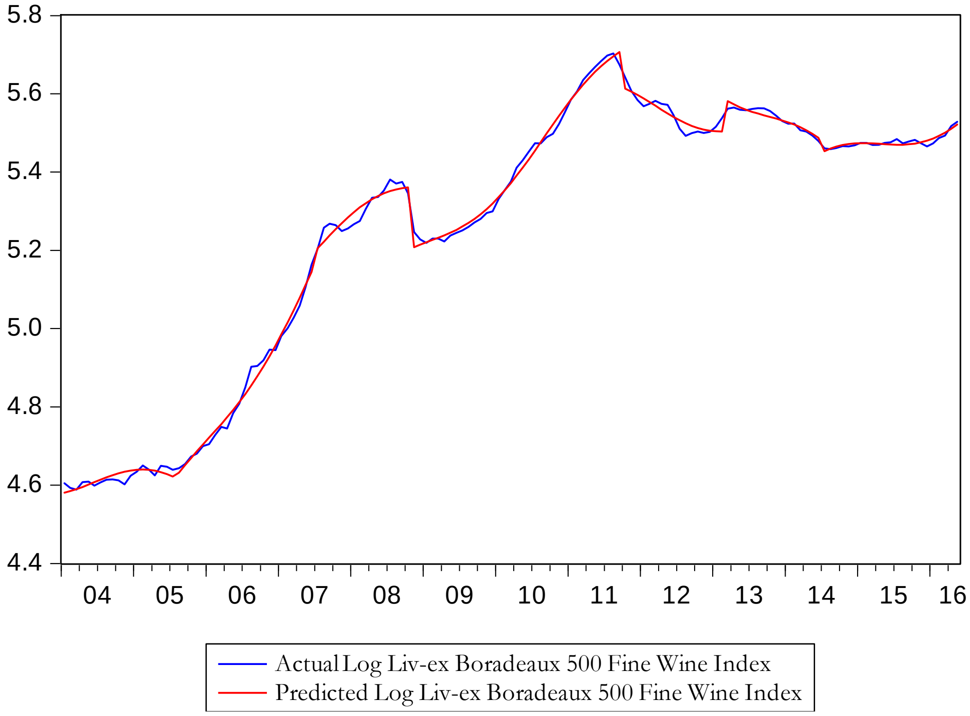

Figure 1d. Liv-ex 1000 Fine Wine Index

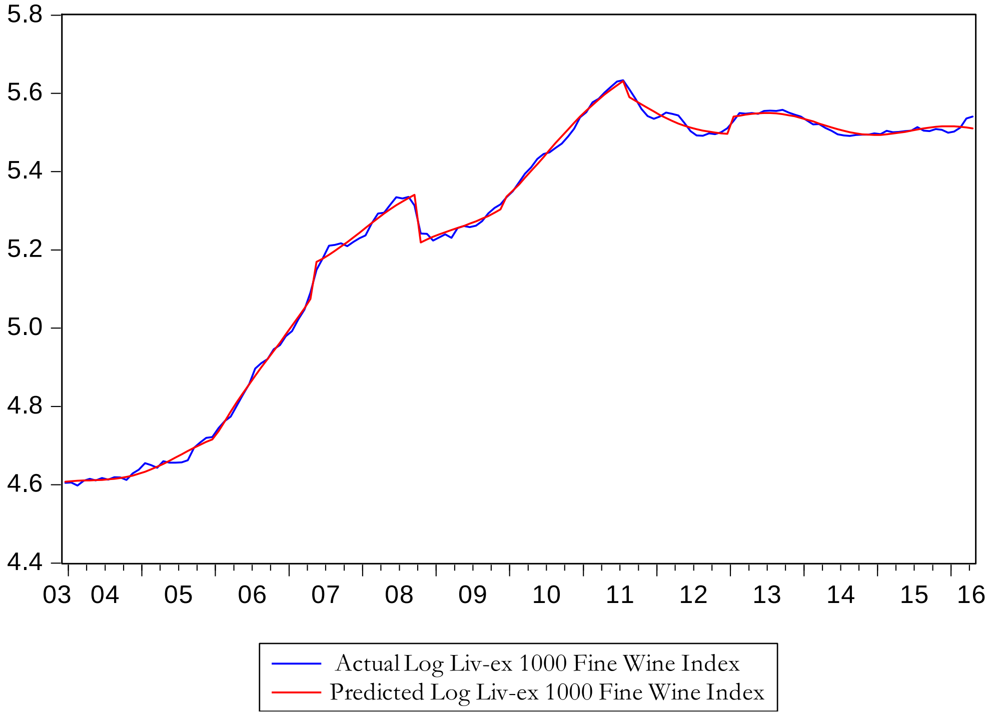

Figure 1e. Liv-ex Investables Fine Wine Index